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SOUND PATTERNS REVEAL SOIL ROUGHNESS AND POROSITY

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INTRODUCTION

Sound reflections show promise as a measuring tool for some physical properties of the soil surface (Sabatier et al. 1990). Soil surfaces in field conditions always contain pores and include roughness of some form. Large pores tend to slow water erosion by allowing water to infiltrate. Small pores slow the infiltration of water. Rough surfaces contain catchment volumes for local ponding of water. Smooth surfaces provide little resistance to flow of water and do little to slow erosion by either wind or water. Changes in roughness, for example a loss from slaking or an increase from a tillage operation, will influence the susceptibility of a soil to erosion by wind or water. Currently we have neither a rapid technique for monitoring the effect of alternative management practices on soil surface roughness and porosity, nor a way to determine the stability of that surface. The development of a tool that can rapidly detect pores in the soil surface and provide a measure of surface roughness will allow more rapid evaluation of alternative practices for erosion control than is now possible.

Sound reflection from any surface is dependent upon the size of pores in that surface and upon its texture or roughness (Zwikker and Kosten, 1949). Theoretical computations are available that allow the estimation of porosity and roughness of a surface based on the pattern of reflection of sound from that surface (Sabatier et al. 1993, Attenborough, 1995). The objective of this paper is to report the comparison of predicted and actual reflected sound patterns over flat and roughened soil surfaces with known porosity and roughness. Agreement of observations with predicted patterns will lead to procedures for extracting porosity and roughness values from observed sound patterns above the surfaces in production fields.

METHODS

Sound patterns between a heavy duty acoustical speaker and a pair of conventional dynamic microphones were recorded above a fine and a coarse textured sand (fig. 1) with a variety of roughened surfaces (Sabatier et al. 1993). Particle size distribution of the sands is shown in fig. 2. Both sands were level to the top of 18-inch deep 8 ft. x

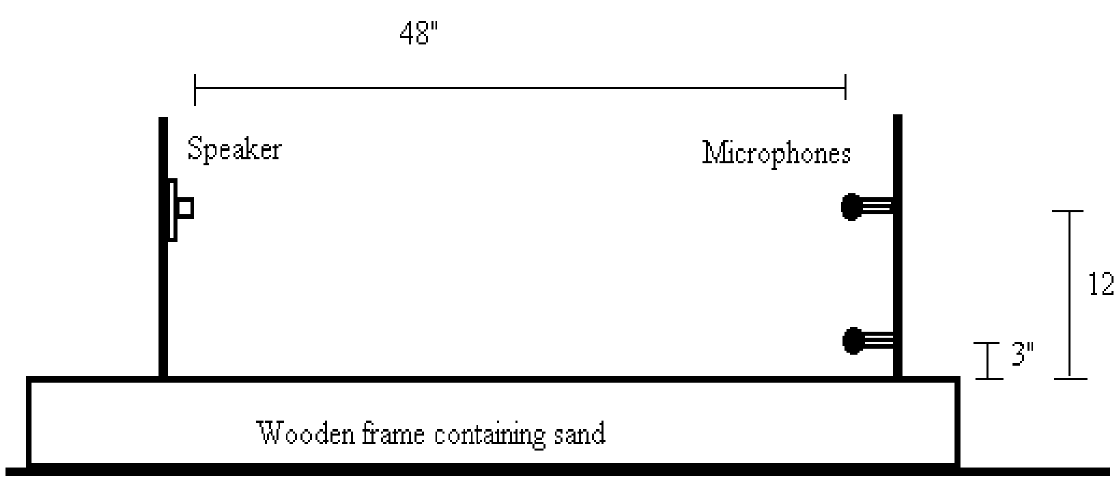

Figure 1. Speaker-microphone arrangement for sound pattern measurement at Pendleton, OR in 1995.

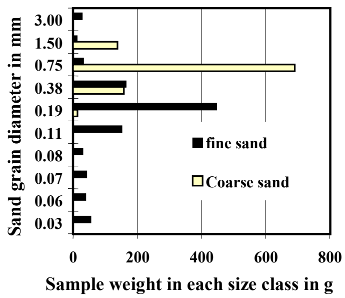

Figure 2. Particle size distribution of coarse and fine sand used for sound pattern measurements in Pendleton OR in 1995.

8 ft. wooden frames. The frames were located in a cultivated field on the Columbia Plateau Research Center grounds at least 300 ft. from the nearest structure.

Three surface conditions were created and observed for the fine sand, and two surface conditions for the coarse sand. A flat surface and a surface with furrows at 3 inches center-to-center spacing were observed on both sands. On the fine sand the small 3-inch furrows were triangular, 3 inches across at the top with a depth of 1.0 inch from the bottom of the furrow to the top of the ridge. In the coarse sand the ridge depth was ½ inch and the shape of the ridge tops was rounded and semicircular. Large furrows at 6-inch spacing were observed on the fine sand. The large furrows were triangular, 4 inches across at the top, 2 inches deep, and were separated by 2 inches of flat sand.

During measurements both the speaker and microphone stands were located within the respective frames that held the sand (fig. 1). All furrows were perpendicular to the line from the speaker to the microphones, filled the 4 ft. space between them, and extended at least 2 ft. on either side of the center line connecting the speaker and microphones. Reflective objects were removed from the surrounding area. Instruments and operator were located 15 ft. or more behind the speaker during any measurement. The speaker-to-upper-micro-phone distance was 4 ft. with the center of the speaker and upper microphone 12 inches above the level surface. The lower microphone was 3 inches from the flat surface, directly below the upper microphone (Fig. 1). All distance measurements were accurate to ±½ inch.

A 20-inch diameter Peavey speaker broadcast sound between 200 and 2,000 Hz. The Prologue model 10L-LC dynamic microphones were not matched so each measurement was taken twice with the microphones interchanged and the signals were averaged to obtain the sound pattern. Data were collected at 16,000 Hz on a high speed dual channel data acquisition board in a portable microcomputer and the sound pattern computed as described by Sabatier et al. (1993). Roughness effects on the pattern were computed according to relationships provided by Attenborough (1995). Computed sound patterns were fitted to those observed by using measured porosity, roughness element size, and source-receiver distances with estimated values for flow resistivity and tortuosity that provided the best fit for each surface condition.

DISCUSSION

Values for the parameters needed for the sound pattern computations are shown in Table 1. Porosity was computed from observed bulk density. Tortuosity and flow resistivity were selected to fit the observed sound patterns. Roughness elements and source-receiver dimensions were measured. Figure 3B and 3C show the fitting of the

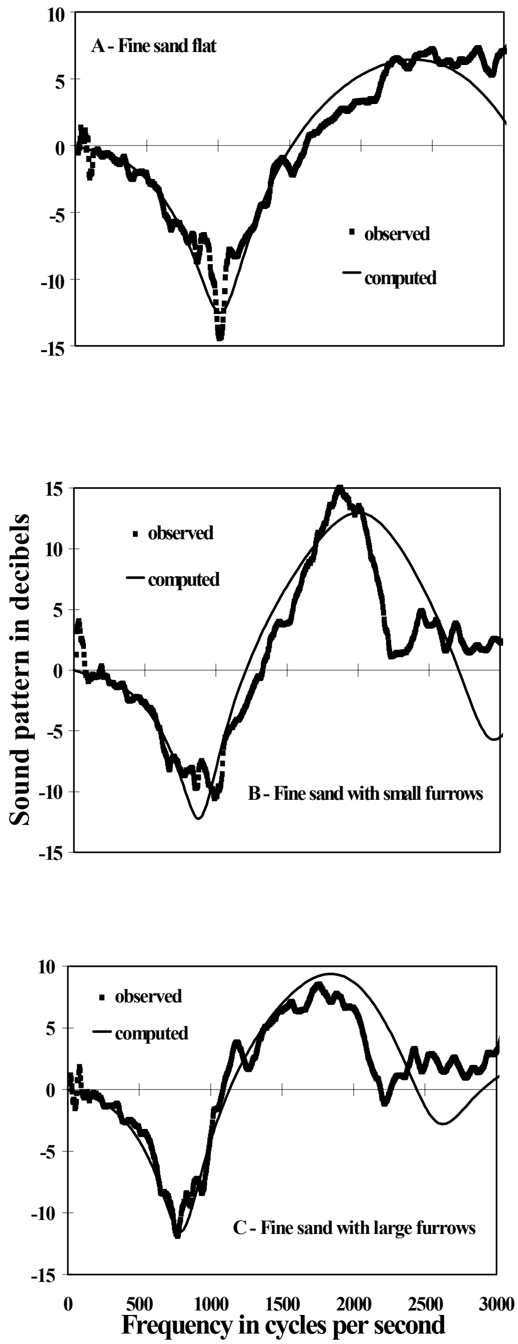

Figure 3. Sound patterns over a fine sand as measured in Pendleton OR in 1995.

observed and computed sound patterns above the roughened surfaces of the fine

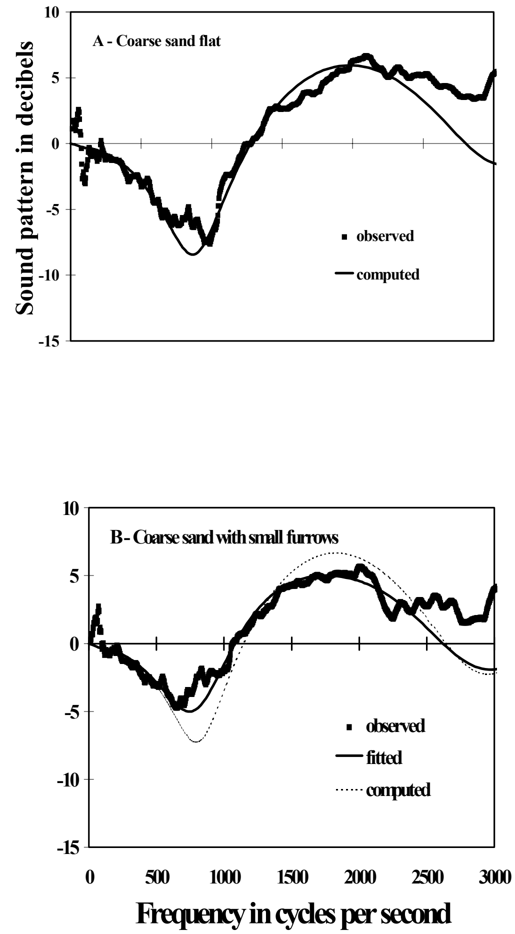

Figure 4. Sound patterns over a coarse sand as measured in Pendleton OR in 1995.

sand using the furrow depths and spacings as observed with the same flow resistivity, porosity, and tortuosity values as for the flat surface in fig. 3A. Agreement between predicted and observed curves was quite good within the range of frequencies observed.

The sound patterns for the coarse sand with flat and furrowed surfaces are shown in figure 4. For the flat surface, agreement between predicted and observed patterns is excellent. To fit the sound pattern above the finely furrowed surface of the coarse sand, the flow resistivity had to

Table 1. Parameter values for matching computed sound patterns with those observed in Pendleton, OR in 1995.

Sand	Surface	Source, Receiver distance inches	Upper mic. and speaker elevation inches	Lower mic. elevation inches	Porosity	Tortuosity	Flow Resistivity mks units	Roughness Element inches		
								height	length	repeat distance
fine	flat	48	12	3	0.43	3	500000	0		
fine	small furrows	48	12	3	0.43	3	500000	1	3	3
fine	large furrows	48	12	3	0.43	3	500000	2	5.5	5.5
coarse	flat	48	12	3	0.39	1.5	140000	0		
coarse	small furrows	48	12	3	0.39	1.5	80000	0.5	3	3

be reduced by almost a factor of 2 (Table 1). The dotted line in fig. 4B is the computed sound pattern with the same flow resistivity as the flat sand. The implication of the reduced flow resistivity is that the "tilling" of the sand surface to create the furrows made the surface more permeable to air than when it was packed flat.

CONCLUSION

Computed and observed sound patterns above both smooth and furrowed surfaces matched for a fine textured sand when actual furrow shapes and sizes are incorporated in the computations. Above a coarse textured sand, sound patterns matched for the furrowed surface only if the value for flow resistivity was reduced below that found for a smooth surface. Since as many as six parameter values enter the sound pattern computations, to determine a unique set of parameter values it may be necessary to observe sound patterns at six or more different speaker-microphone arrangements above each new surface. While such a requirement will increase the time for completing a measurement, the total time required is still only a few minutes. The dimensions of the measuring system must be precisely determined for each field observation. Speaker to microphone distances must be accurate to within 1/16 of an inch. Soil surface to microphone heights must be accurate to better than ¼ inch. A portable frame that will hold the speaker-microphone system rigidly in place relative to one another and to the soil surface is being designed for use in continuing field trials during the summer of 1996.

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